# Fire in an intensive care unit: causes and strategies for prevention

Koravangattu Sankaran, MD, FRCPC, FCCM; Allan Roles, PEng, MBA; Gordon Kasian, MD, FRCPC

Fires in institutions occur frequently and are the cause of a considerable number of casualties.[1-3] Although major hospital fires are rare their potential for disaster is substantial;[4,5] consequently, much time, money and effort go into preventing them. Preventive architectural design, fire drills, staff education and protocols for disaster planning are common in hospitals.[6-9] The occurrence of a fire in an intensive care unit has rarely been reported.[10] We describe two nearly disastrous fires that occurred in 1988 within 4 days of each other in a neonatal intensive care unit (NICU) at the Royal University Hospital, Saskatoon. Fortunately there were no casualties. The subsequent investigation determined the sequence of events that led to the fires, and the lessons learned were incorporated into the reconstruction design.

## Case report

The NICU was constructed in 1982 with fire-retardant materials to comply with national building and fire codes.[11,12] Electrical and gas fittings conformed to electrical and surgical standards for hazard control and to the standards of the Canadian Safety Act.[13,14] The NICU had 30 beds and was equipped to care for newborn infants requiring critical care. All bed spaces were supplied with four oxygen outlets, two compressed air outlets, two suction outlets and eight electrical outlets. Sealed cabinets contained electrical wires and pipes for oxygen, compressed air and suction, running to the ceiling space through a chase. The gas piping system was checked by a certified gas agent after its installation, and periodic checks were made for gas leakage.

On the night of Aug. 4, 1988, a nurse was changing isolettes for one of the infants in the first bay. This was done routinely once every 3 days. When she pulled the isolette plug she noted a spark and smoke erupting from the socket. On closer observation she saw a ball of fire in the socket and felt intense heat on the counter surface of the cabinet. A fire alarm was initiated, the infants were evacuated from the bay, and the area was cordoned off. On the night of Aug. 8, 1988, a nearly identical incident occurred in another bay. This time the entire unit was evacuated. In each case the fires burned themselves out within minutes. The investigations begun after the first incident were intensified after the second.

### *Evacuation*

During the second fire 24 infants and several parents were evacuated without incident. The babies who were in stable condition (convalescent) were moved to the neighbouring pediatric ward. Of the five oxygen-dependent infants requiring mechanical ventilation one was paralyzed with pancuronium bromide and had bilateral chest tubes in place. Three people were needed to move this infant. Fortunately the pediatric intensive care unit could accommodate two infants; the remaining babies were lodged in the infant pediatric ward. Although the neonatal unit was on the same floor as the pediatric wards and close to them, there were difficulties in supplying oxygen to these infants until after the transfer was complete. Manual ventilation with room air was achieved by means of a self-inflating air bag during the transfer. The infants suffered no ill effects.

During the evacuation the smoke was thick and grey, irritating the eyes of the staff. The entire NICU

*Drs. Sankaran and Kasian are with Neonatal Services, Department of Paediatrics, University of Saskatchewan, and Mr. Roles is with the Department of Engineering and Maintenance, Royal University Hospital, Saskatoon, Sask.*

*Presented in part at the Pediatric Critical Care Colloquium, Waterville Valley, NH, Oct. 1 to 4, 1990.*

*Reprint requests to: Dr. Koravangattu Sankaran, Department of Paediatrics, Royal University Hospital, Saskatoon, SK S7N 0X0*

was sealed off. Hospital maintenance and city fire department staff controlled the fire, and exhaust fans were used to pump the smoke from the unit.

*Investigation*

An incident had occurred several months before the fires that should have served as a warning signal. A curl of smoke had been noted from a socket on the chase and brought to the attention of the hospital maintenance staff. A significant collection of lint had been found in the socket, and so all sockets had been vacuumed. At the time it did not occur to anyone to check the inside of the sealed cabinets or the inside of the chase for lint accumulation (Fig. 1).

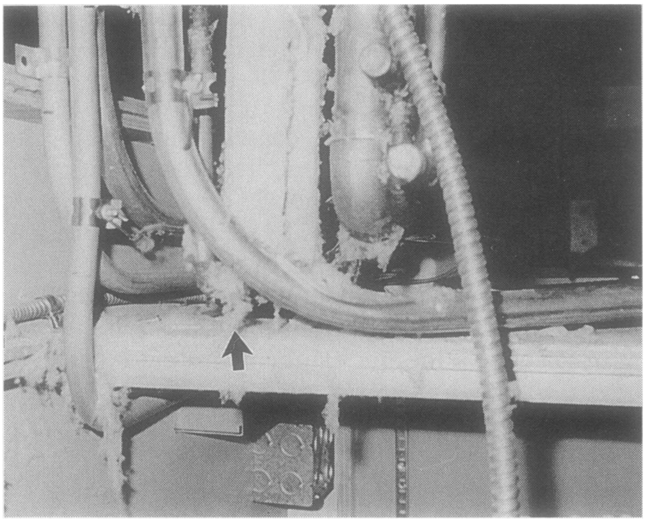

**Fig. 1: Opened cabinets and chase, showing extensive accumulation of lint (arrow).**

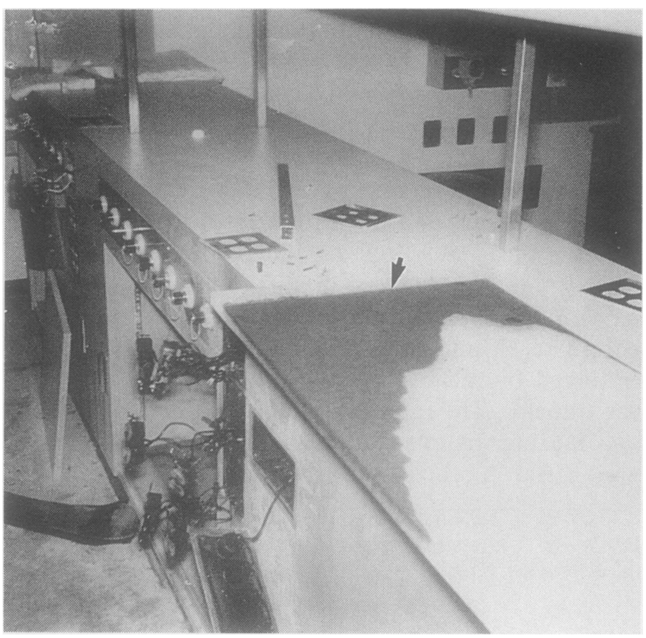

**Fig. 2: Arrow indicates burn pattern on top surface of bottom slab of cabinet.**

After the evacuation the cabinets were opened. There was not only severe damage near the top of each cabinet — where the fire started — but also intense charring on the top surface of the bottom slab (Fig. 2) and even on the linoleum floor on which the cabinet sat. In addition, there was severe charring along the electrical fittings and conduits (Fig. 3). Since fires normally burn upward the burn pattern proved confusing for the investigators.

Because there had been more than one episode and because of the potential for disaster several experts were called in to determine the cause of the fires. In addition to the hospital staff there were three people from the city fire department, two from Saskatchewan Government Insurance, a provincial electrical inspector, three representatives from engineering and architectural firms, an observer from the Stinson-Eisler Adjustment Bureau, two consultants from the Department of Chemistry, University of Saskatchewan, and one consultant from the Saskatchewan Research Council. They took 9 days of intensive searching to solve the enigma.

The first suspicion was of an electrical cause, but two independent assessments revealed that the wiring met all the standards of the Canadian Standards Association (CSA). The pattern of charring on

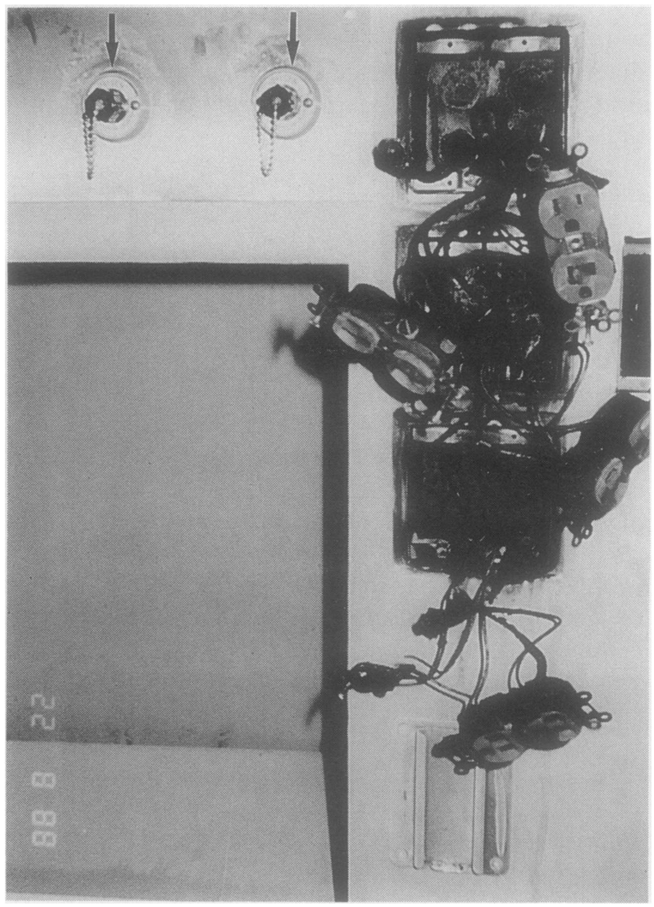

**Fig. 3: Fire damage of electrical fittings. Arrows indicate oxygen outlets, which are located next to electrical outlets.**

the bottom slab of the cabinet (Fig. 2) raised the possibility of chemical spillage. The hospital welding shop was quickly transformed into a laboratory. Cabinet replicas were made, and various chemical materials spilt into the cabinet to induce a fire. However, the pattern of damage could not be matched.

Finally, a multifactorial theory was proposed and tested. It was demonstrated that because of a pressure difference between the unit and the inside of the cabinets oxygen-rich air streamed through the electrical sockets into the cabinets. Between the first and second fires the air in the cabinets was checked and, indeed, found to contain more oxygen than normal atmospheric levels. Large quantities of free-flowing oxygen were used to run ventilators and resuscitation bags. Although tests revealed no leaks in the pipes the oxygen outlets leaked at the site where flow meters had been inserted. This leakage and the proximity of the oxygen outlets to the electrical outlets (Fig. 3) contributed to the streaming. In addition to oxygen the air flowing through the electrical sockets carried small amounts of lint, which accumulated inside the electrical boxes and the cabinets. When an isolette was unplugged a spark ignited the oxygen and lint, allowing the cabinet's otherwise relatively fire-resistant materials to burn easily until the oxygen was consumed.[15] The introduction of oxygen-rich air and lint into the experimental cabinet reproduced the pattern of fire damage. A videotape of the recreated fire sequence is available from the Royal University Hospital.

## Comments

A review of the medical literature failed to reveal reports of a similar occurrence. In general, medical staff are ignorant about institutional fires and their causes. Therefore, we strongly believe that an appreciation of the risk factors identified here is important to everyone involved with the management or construction of critical care hospital areas.

Fires normally burn upward; the burn pattern of our fires was downward. The slow streaming of oxygen-rich air into the sealed cabinet and the greater heaviness of oxygen compared with room air made it possible for the oxygen to gravitate to the bottom of the cabinet. When the lint caught fire it was fuelled by the oxygen and burned downward. Fortunately the oxygen was consumed before the high-pressure pipes could burst, thus preventing a major disaster.

There are no design-related safety codes specifying the location of oxygen outlets with respect to electrical sockets.[16] We have reported the fires to the CSA and have suggested the development of standards for future hospital designs.

The renovation of our NICU took into account the factors that contributed to the fires. The cabinets are no longer sealed and are left open to the ambient air from underneath to ensure that no streaming occurs. This design allows lint and spilled materials to be cleaned up. The electrical sockets are now above rather than below the oxygen outlets.

The evacuation of oxygen-dependent infants from the NICU posed a problem, as portable oxygen sources were not readily available. It is now our policy to keep a freestanding oxygen tank close to all infants who are oxygen dependent.

Up until 4 years ago all isolettes purchased by the hospital did not have power switches; therefore, the only way to start or stop them was to unplug them. After the fires, hospital biomedical technologists converted the older isolettes by installing power switches similar to those on new isolettes.

We thank the staff of the Neonatal Intensive Care Unit and the Department of Engineering and Maintenance, Royal University Hospital, Saskatoon, for their help. We also thank the Royal University Hospital Foundation for encouragement and financial assistance.

## References

1. Moody DL, Thalhuber J: Metropolitan medical office building fire: the event and its consequences. *Minn Med* 1979; 62: 279–281
2. Sharpe DT, Roberts AH, Barclay TL et al: Treatment of burns casualties after fire at Bradford City football ground. *BMJ* 1985; 291: 945–948
3. Books E: Ash Wednesday. *Nurs Mirror* 1985; 161 (17): 30–31
4. Hart RJ, Lee JO, Boyles DJ et al: The Summerland Disaster. *BMJ* 1975; 1: 256–259
5. Hacon WS, Mann AW: Fire at Yellowknife. *Can Hosp* 1966; 43: 49–51
6. Nasel EL, Perdue M, Hayes JD et al: Drill prepares OR for fire emergency. *Hospitals* 1973; 47 (15): 99
7. Cruickshank KJ: Fire and evacuation planning in hospitals. *Australas Nurses J* 1978; 1 (Sept 8): 7–14
8. Fire precautions in hospitals. *Lancet* 1969; 2: 92–93
9. Emmert KD: Disaster planning: perspectives in practice. *J Am Diet Assoc* 1982; 81: 715–718
10. Farman JV: Fire risks in intensive care units and operating theatres — evacuation of surgical patients. *Proc R Soc Med* 1976; 69: 603–604
11. *Report of the Associate Committee on the National Building Code*, 8th ed, National Research Council of Canada, Ottawa, 1980
12. *Report of the Associate Committee on the National Fire Code*, 4th ed, National Research Council of Canada, Ottawa, 1980
13. Kilpatrick DG, Kilpatrick LB, Stephenson JE: Electrical safety standards in the health care delivery system. *CRC Crit Rev Bioeng* 1972; 1: 289–332
14. Laufman H: Surgical hazard control: effect of architecture and engineering. *Arch Surg* 1973; 107: 552–559
15. *Manual on Fire Hazards in Oxygen-Enriched Atmospheres*, National Fire Protection Association, Ottawa, 1985: 53–58
16. Gardner VF: NFPA hospital safety standards: Compliance by hospitals with the National Electrical Code can effectively minimize electrical hazards. *Hospitals* 1971; 45: 102–105